Assimilative Capacity of Fish Farm Environments as Determined by Benthic Oxygen Uptake Rate: Studies Using a Numerical Model

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Japan has succeeded in increasing its aquaculture production, supported by development of production techniques and the economic growth.

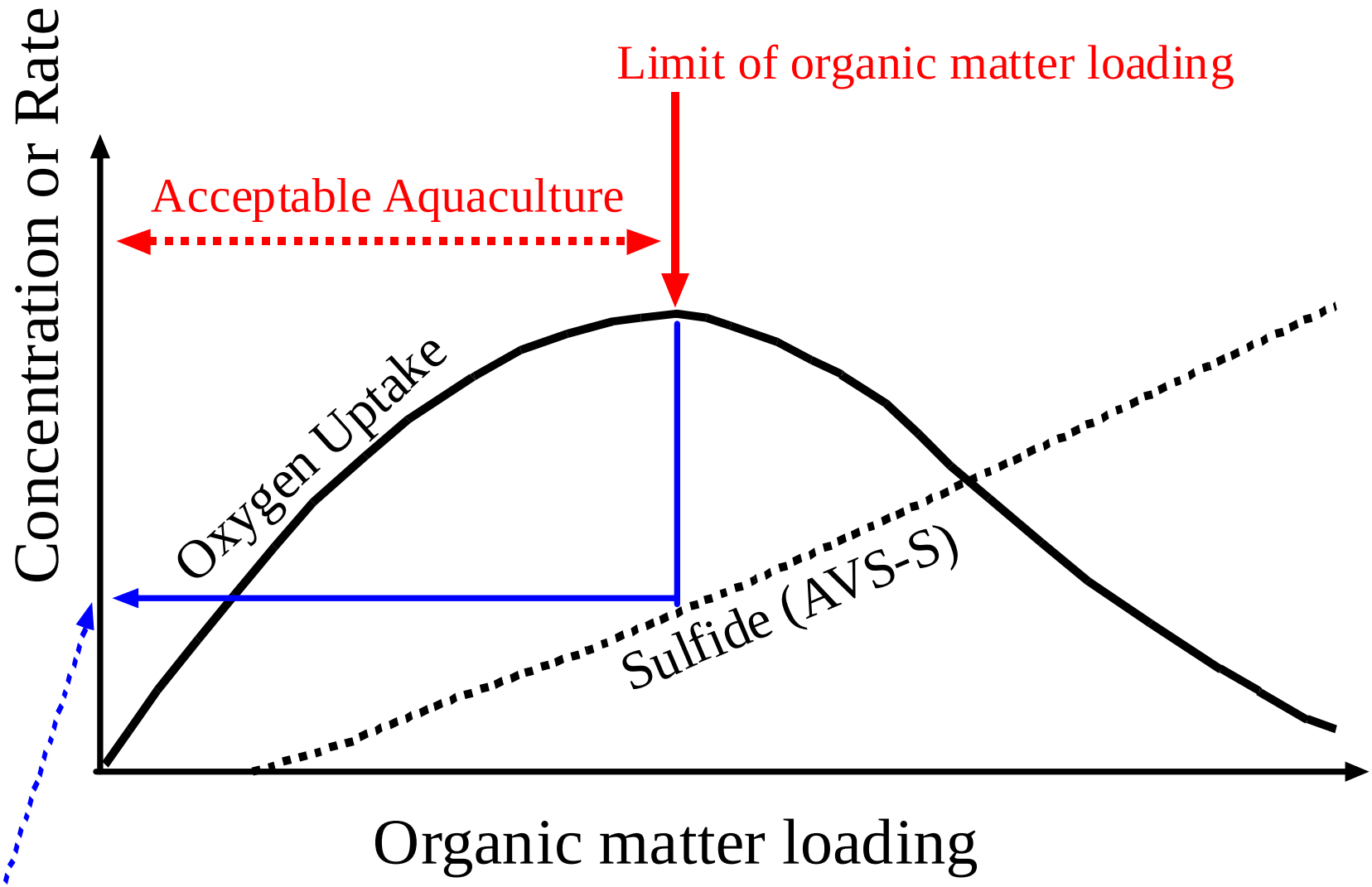
However, overstocking of aquaculture pens have caused deteriorations in the environmental condition of aquaculture ground.

In order to promote improvements in the environmental quality of aquaculture grounds and maintain suitable conditions for stable aquaculture production, the Low to Ensure Sustainable Aquaculture Production was established in 1999.

Environmental criteria used in the Law

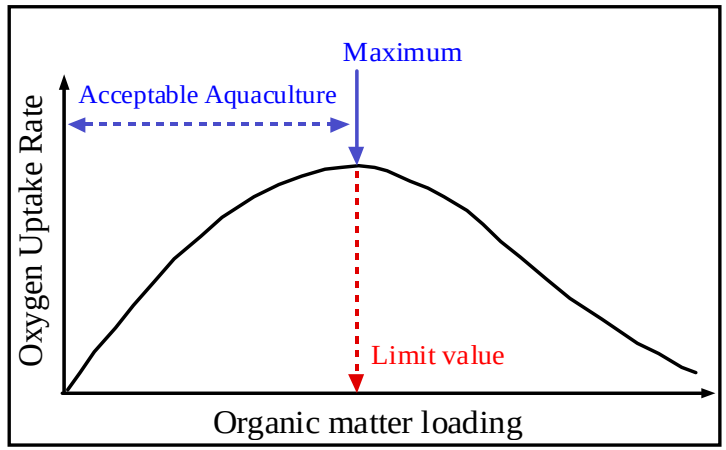
Item	Indicator	Criterion for identifying healthy farms	Criterion for identifying critical farms
Water in cages	Dissolved oxygen	>4.0 ml/l	<2.5 ml/l
Bottom environment	Sulfide (AVS-S)	Less than the value at the point where the benthic oxygen uptake rate is maximum	>2.5 mg/g dry sediment
	Benthos	Occurrence of animals throughout the year	Azoic conditions during >6 months

Concept of environmental criterion (indicator: AVS-S)



Determination of the standard value

We have to detect the maximum of oxygen uptake rate relative to organic matter loading rate.

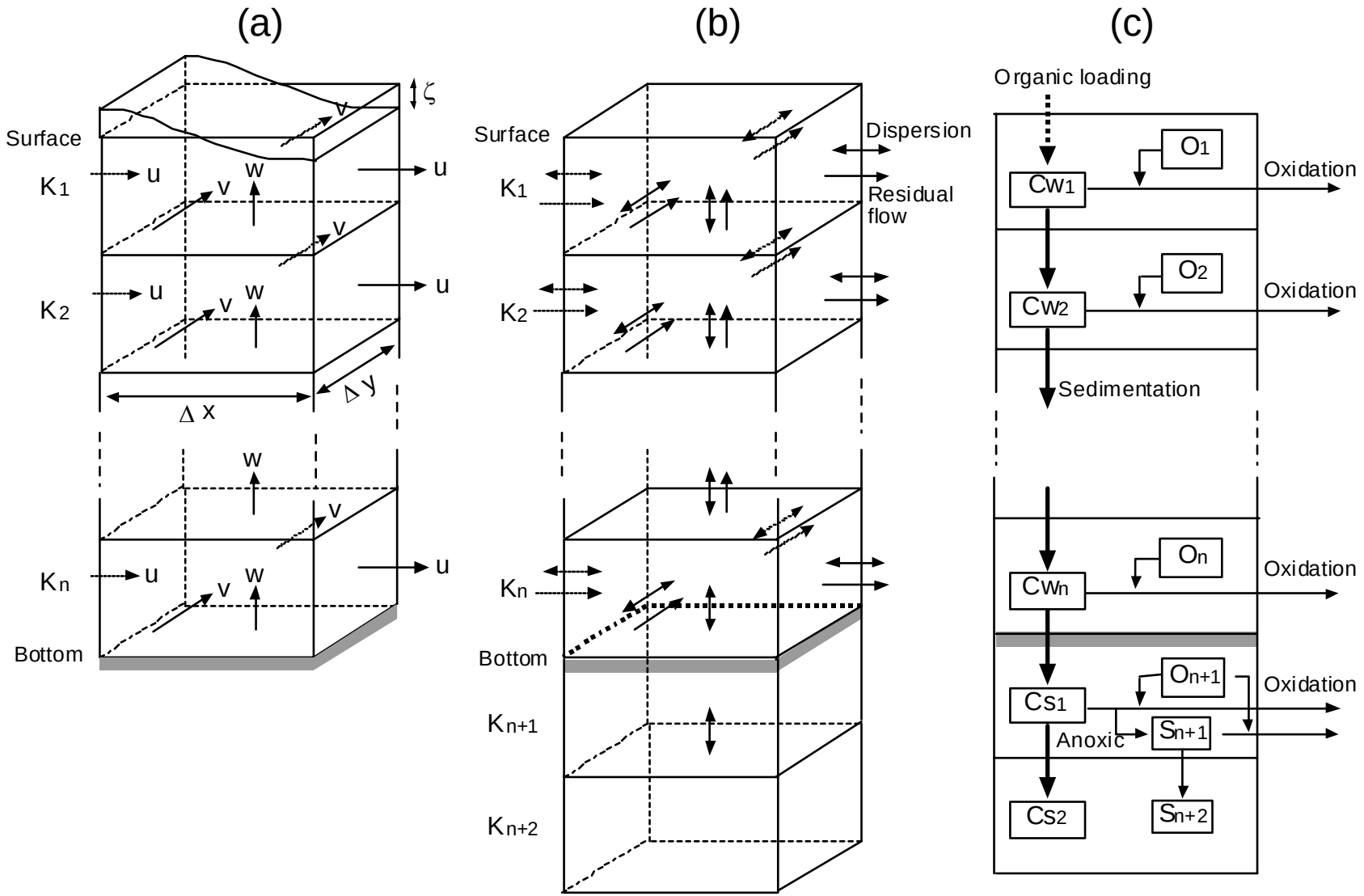


Methods for detecting the maximum:

1. Change of organic matter loading rate in an existing farm
   → Impractical.
   ← Numerical simulation
2. Investigation of oxygen uptake rate in similar farms
   → Impractical
3. Investigation of oxygen uptake rate in several points in a farm
   → Wrong

→ We have developed a numerical model

Schematic views of the numerical model

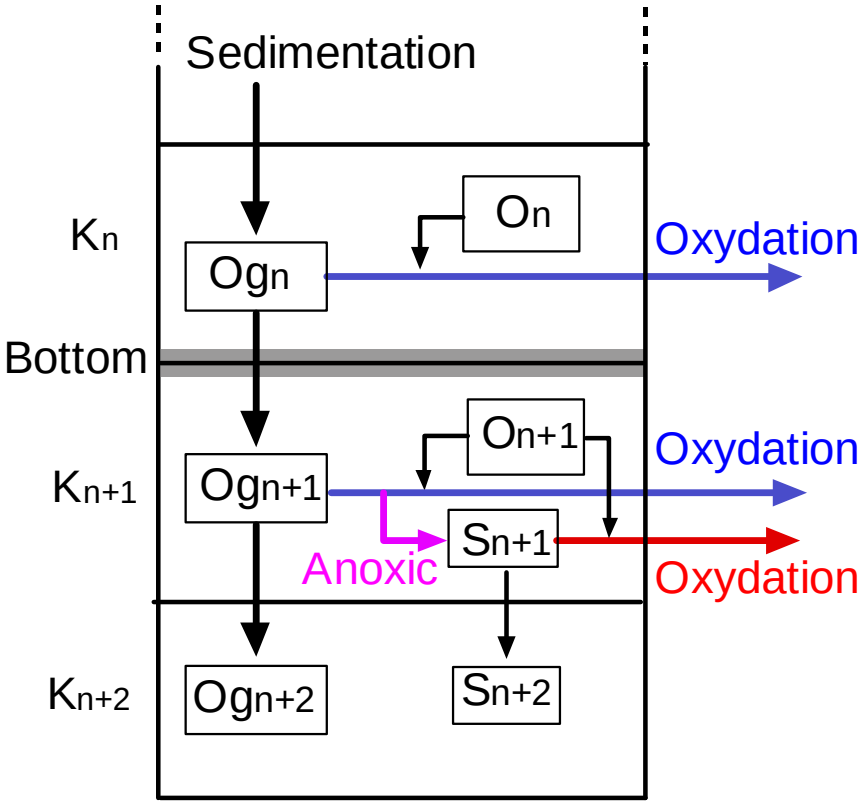


Multi-level density flow model

Advection and diffusion of organic matter & DO

Flow of organic matter

Flow of organic matter and the relational equations



O_n: Dissolved oxygen

Og_n: Organic matter

S_n: Reduced substance in the K_n layer.

Equations

Aerobic degradation rate

$$= a_1 (O_n - a_2) Og_n$$

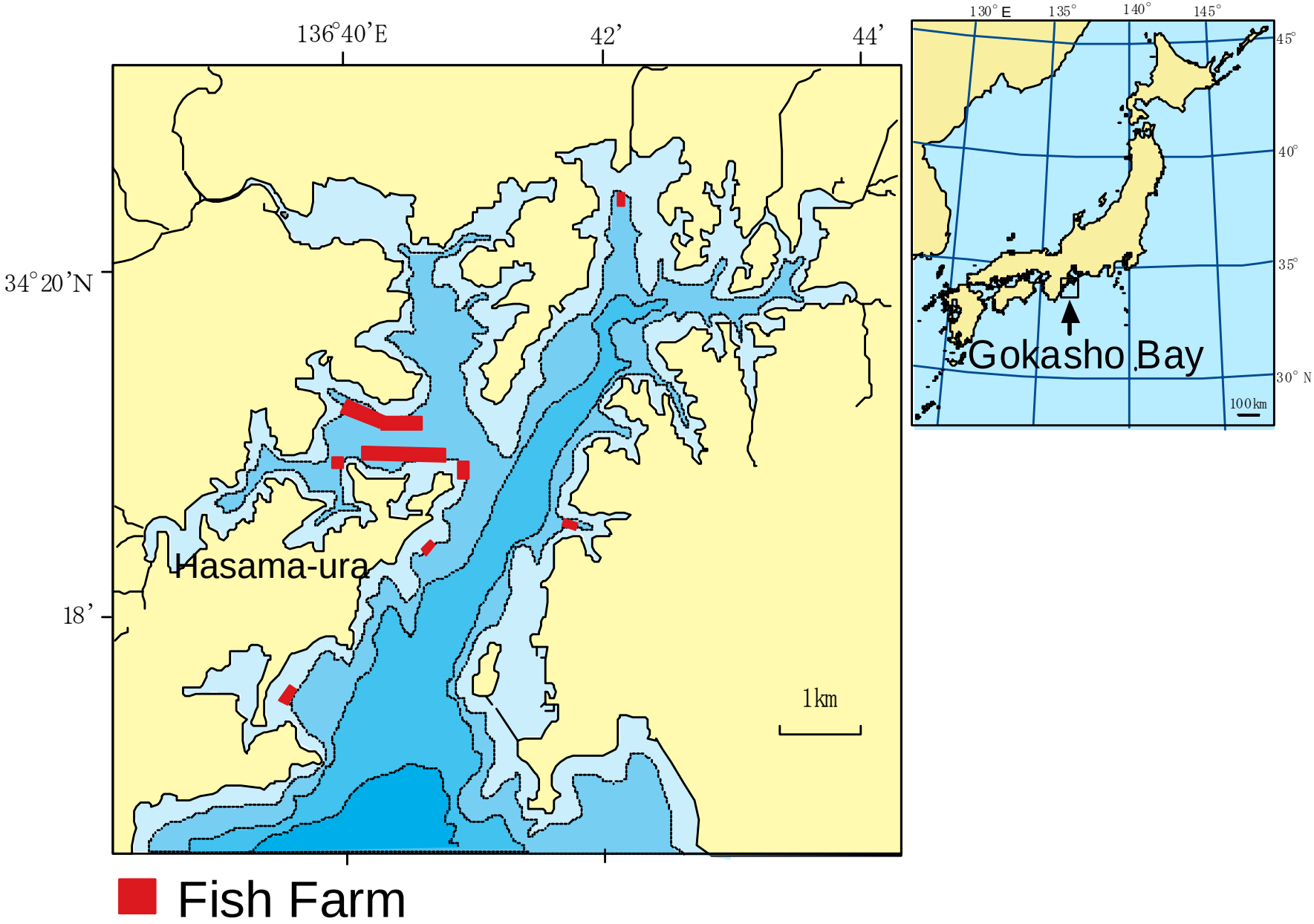
Anaerobic degradation rate

$$= a_3 Og_n / (O_n - a_4)$$

Chemical oxygen uptake rate

$$= a_5 Og_n O_n$$

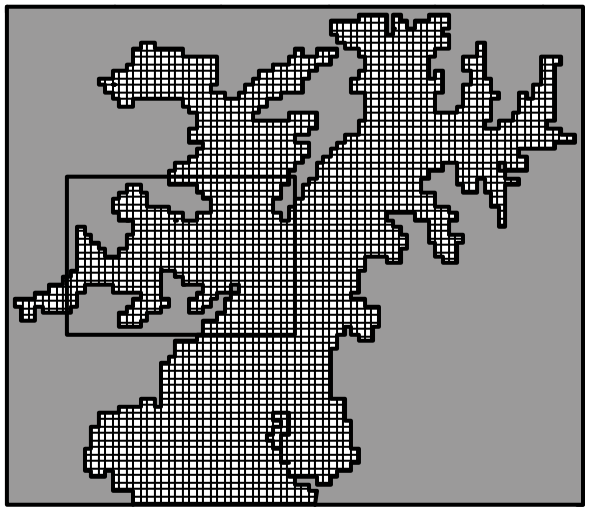
(Omori *et al.*, 1994)



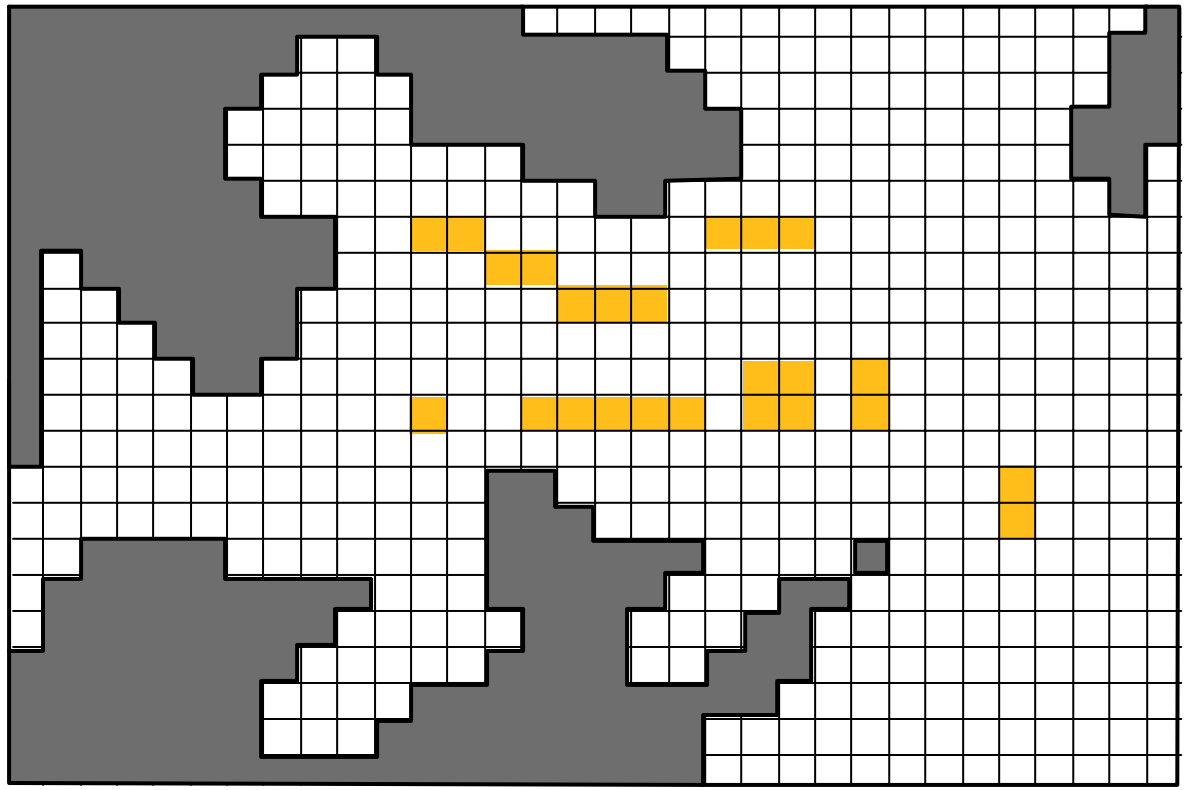
Map of Gokasho Bay

Red sea breams (*Pagrus major*)

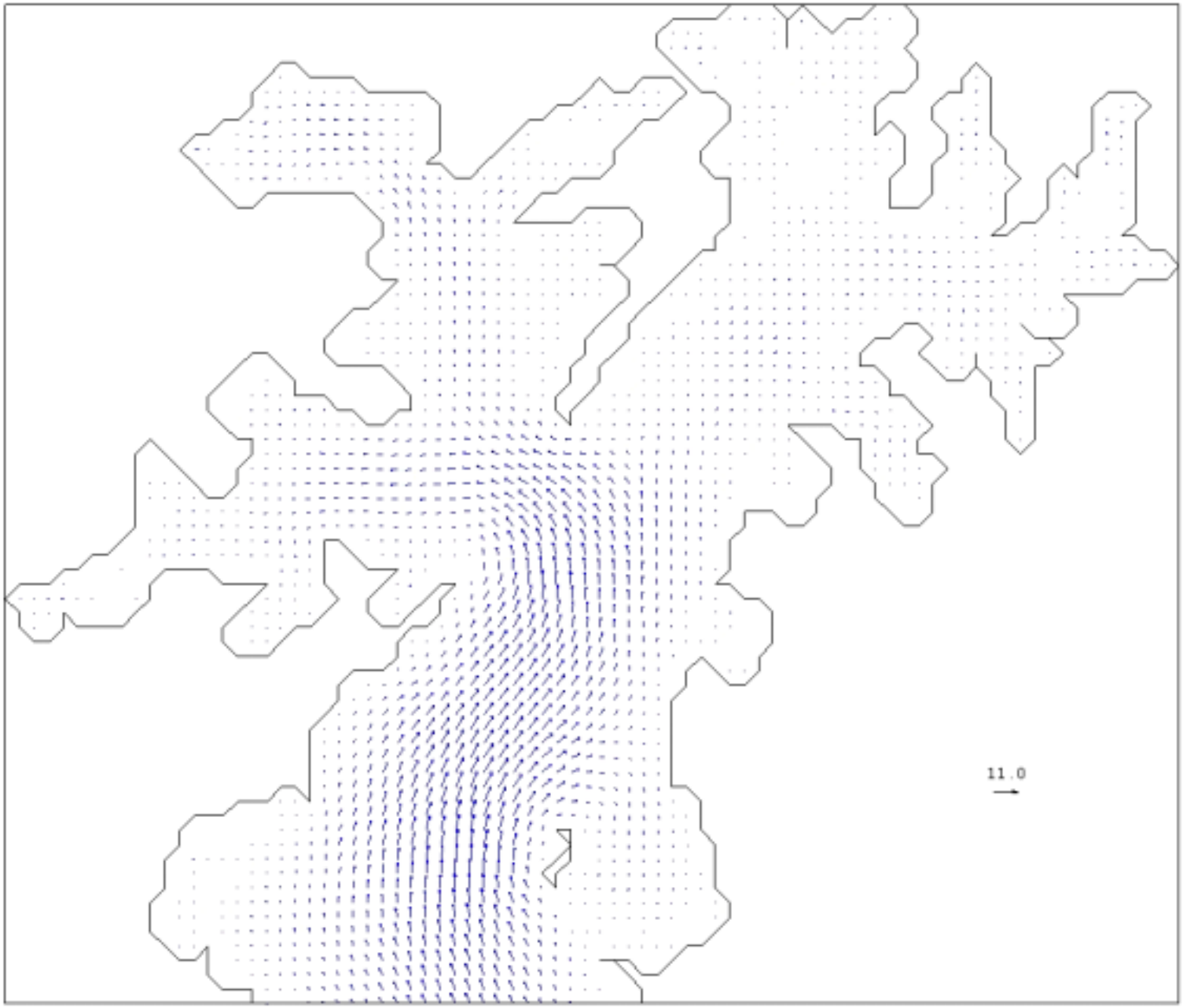
Model Geometry



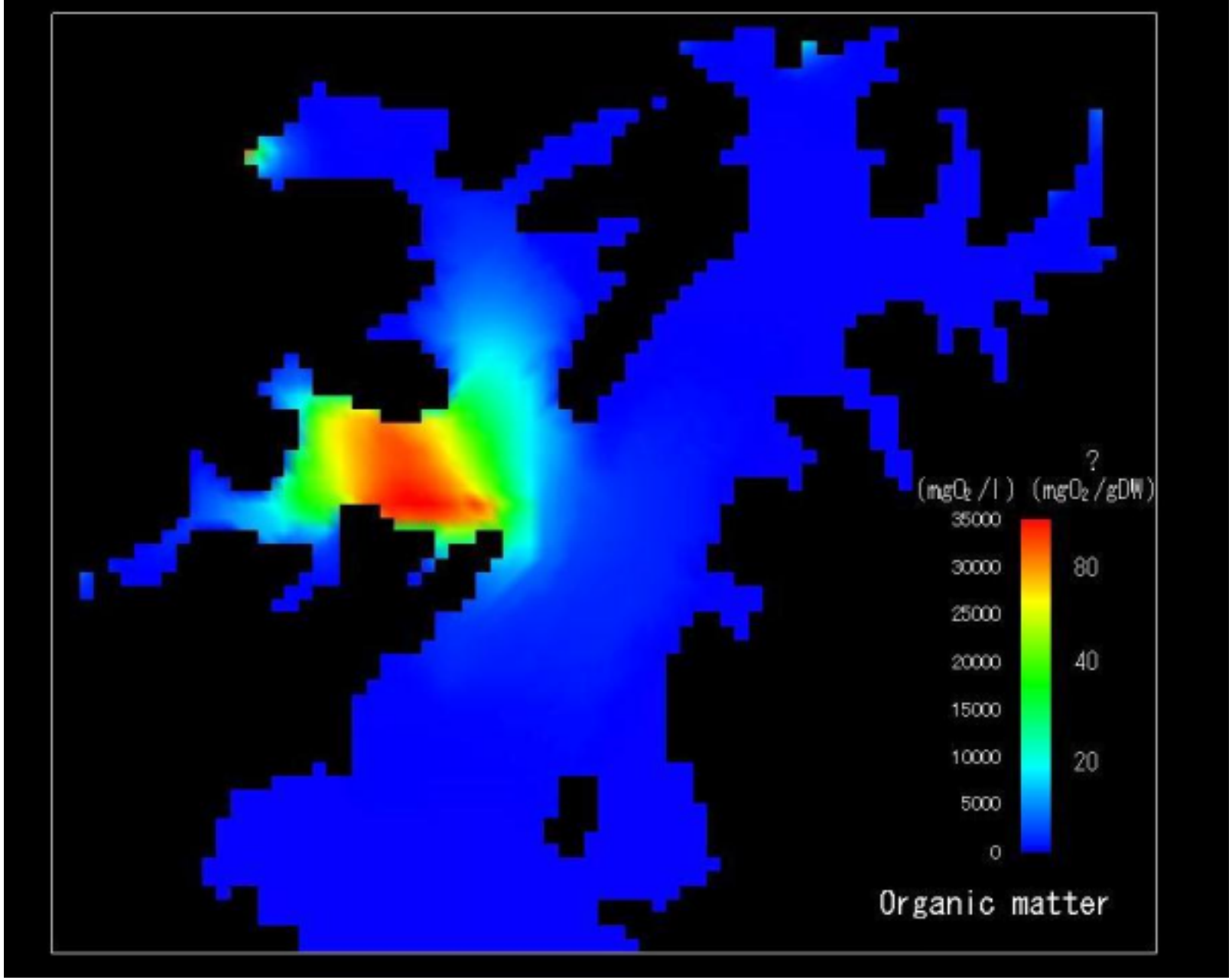
Gokasho Bay



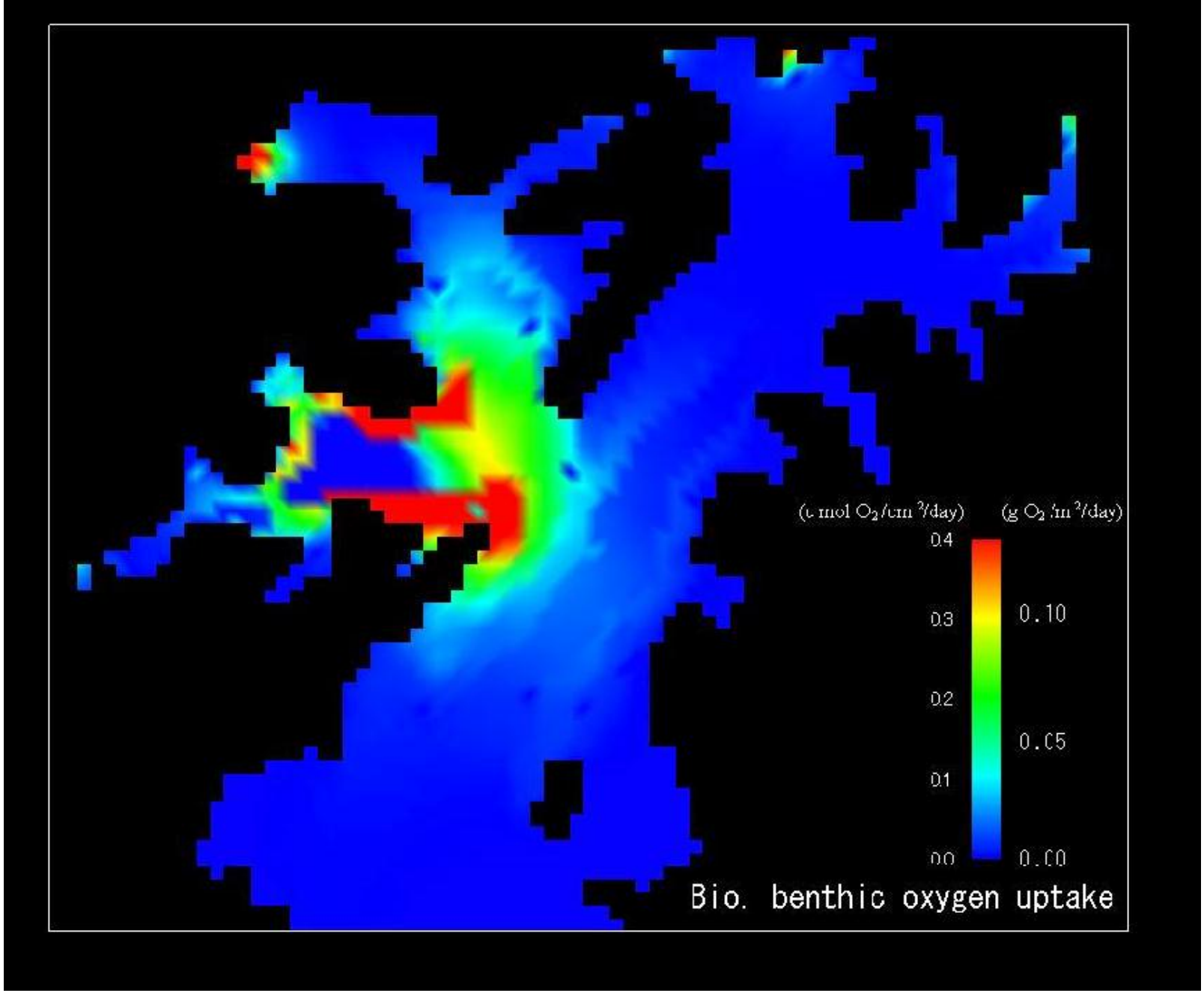
Fish Farming site



Tidal current calculated by the model

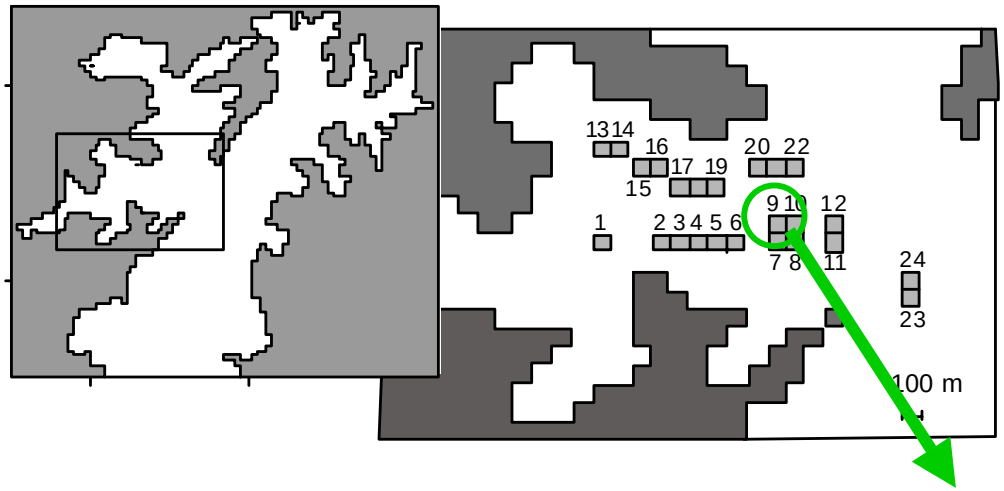


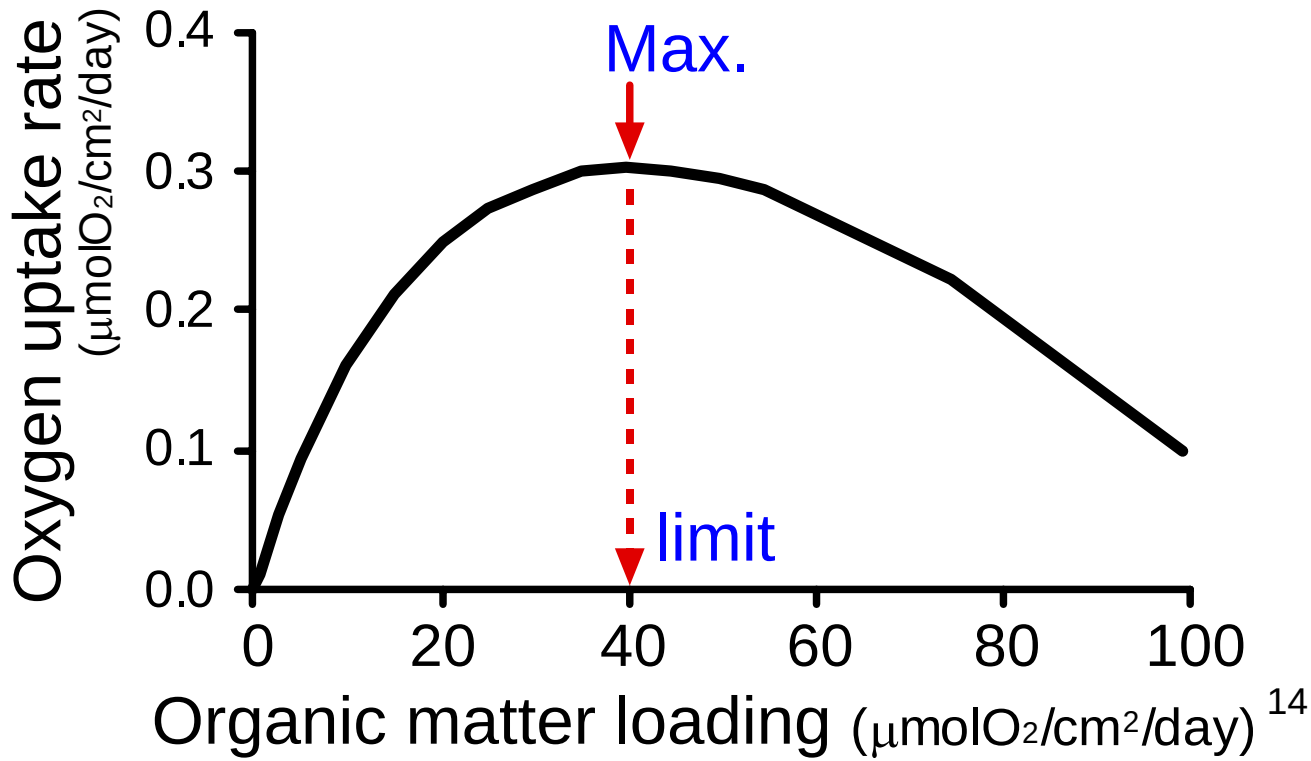
Organic Matter Content of the Sediment



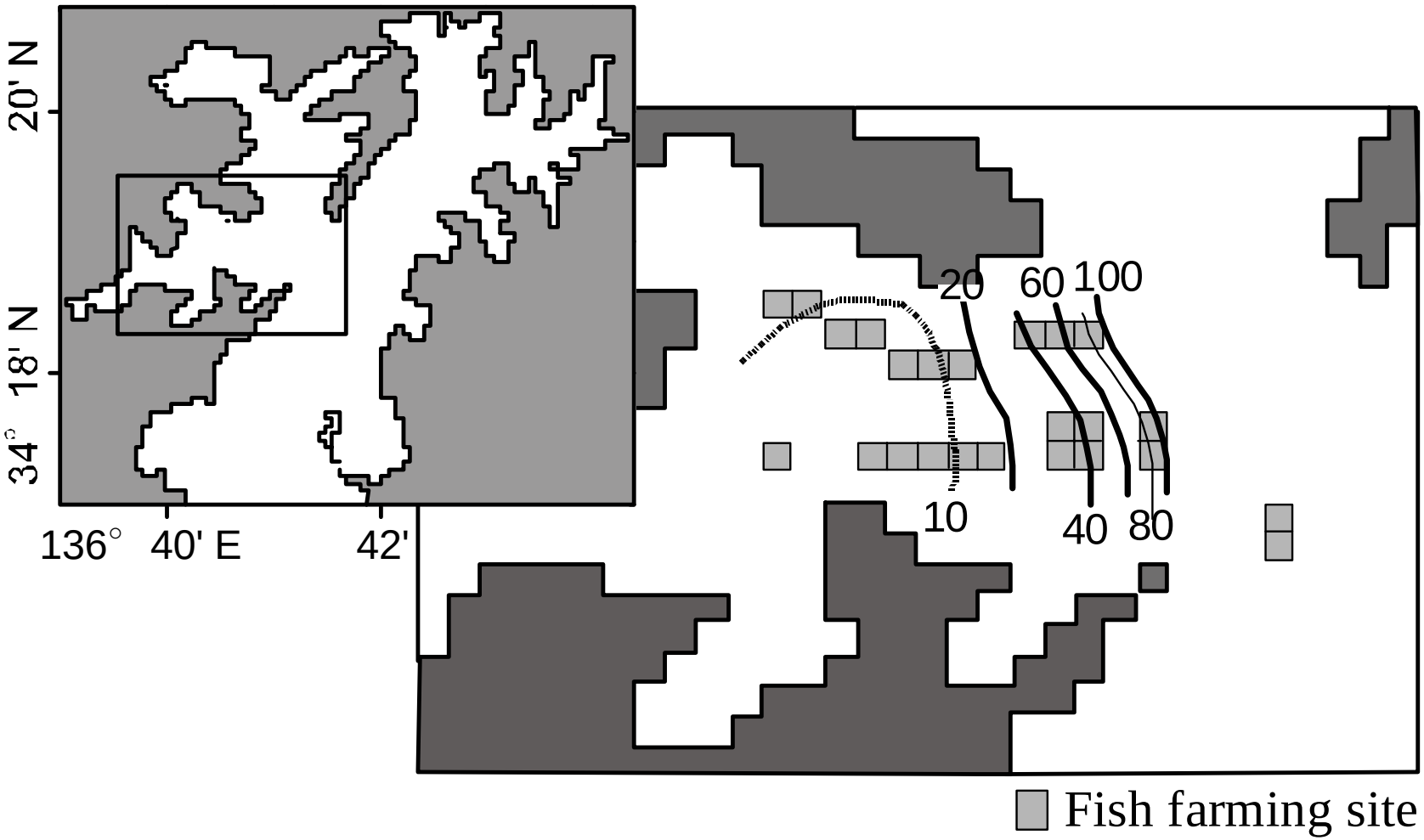
Benthic Oxygen Uptake Rate

Estimation of the Maximum and the Limit Value

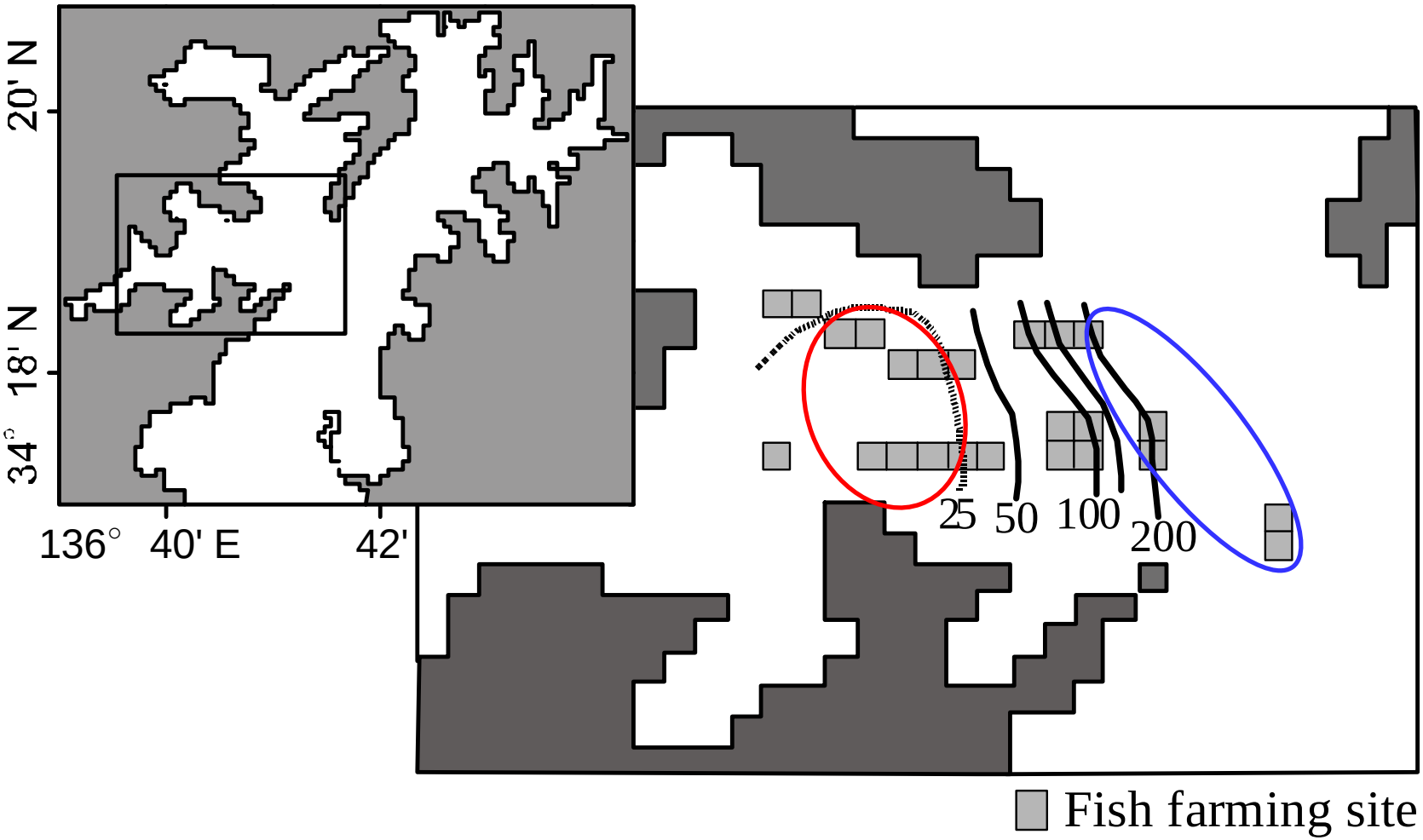




Limit Values of Organic Matter Loading Rate (μ mol $O_2/cm^2/day$)



Ratio of the limit value to the real organic matter loading rate (%)



Conclusion

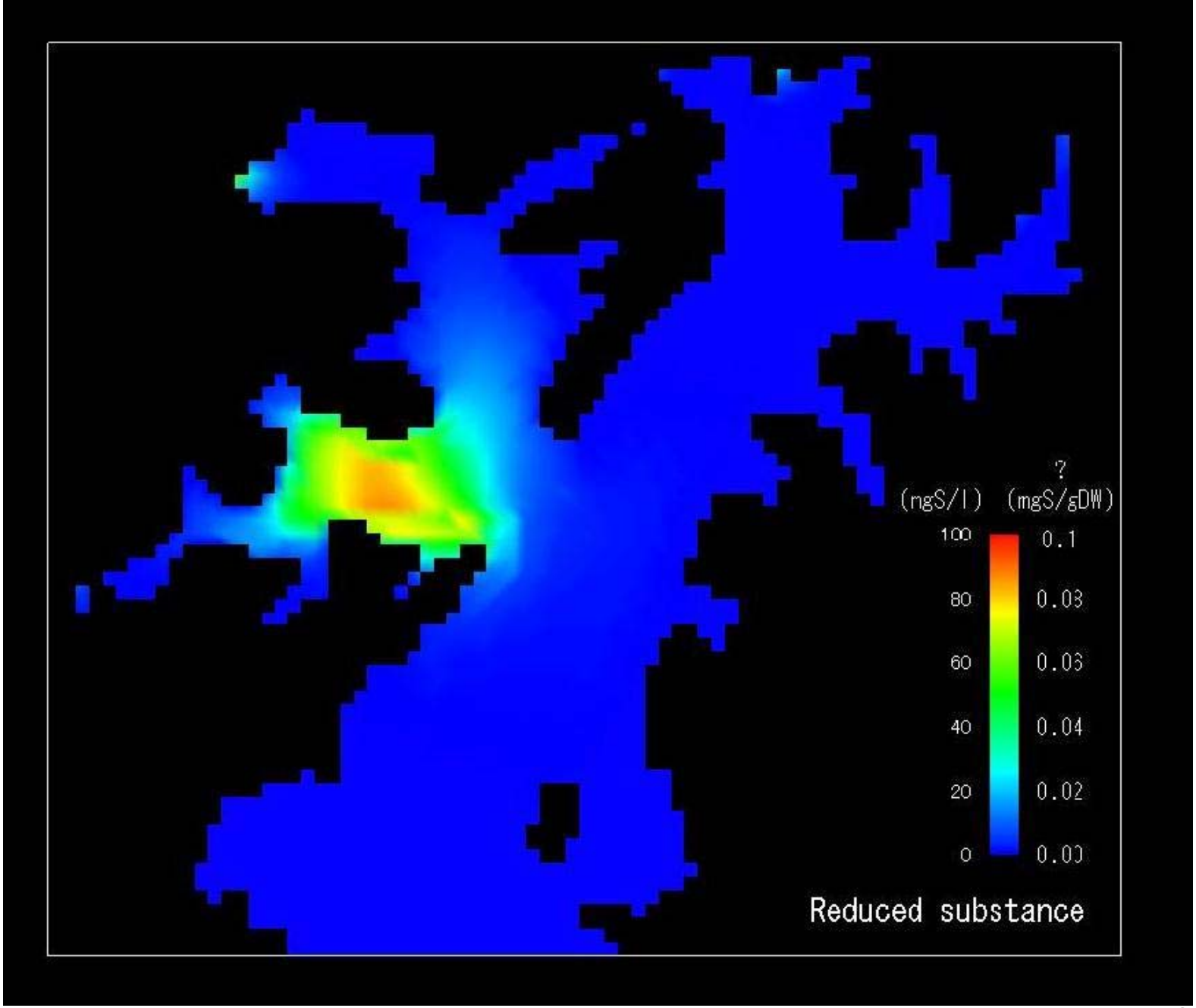
The numerical model is an effective tool to determine the limit values of organic matter loading from fish farms based on the criterion determined by the Law.

The numerical model may be effective for suggesting appropriate spatiotemporal use of aquaculture ground.

Concepts widely used in aquaculture management (Fernandes *et al.,* 2001)

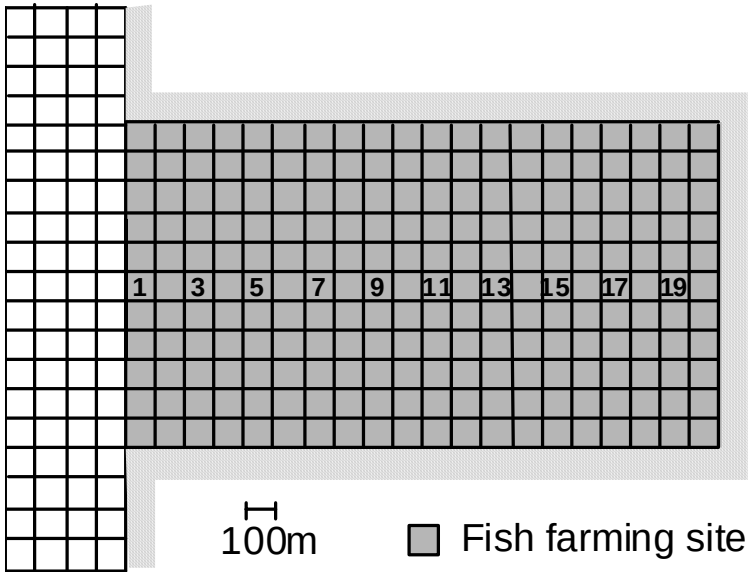
Term	Definition
Carrying capacity	of a defined area refers to the potential maximum production of a species or population that can be maintained within that area in relation to the available food and environmental resources.
Holding capacity	is the potential maximum production which is limited by a non-trophic resources
Assimilative capacity	is the ability of an area to maintain a 'healthy' environment and 'accommodate' wastes.
Production capacity	is the maximum tonnage level that can be attained without producing a negative impact on the environment and on the farmed stock.
Environmental capacity	refers to the ability of the environment to accommodate a particular activity or rate of activity without an unacceptable impact.

Picture 2

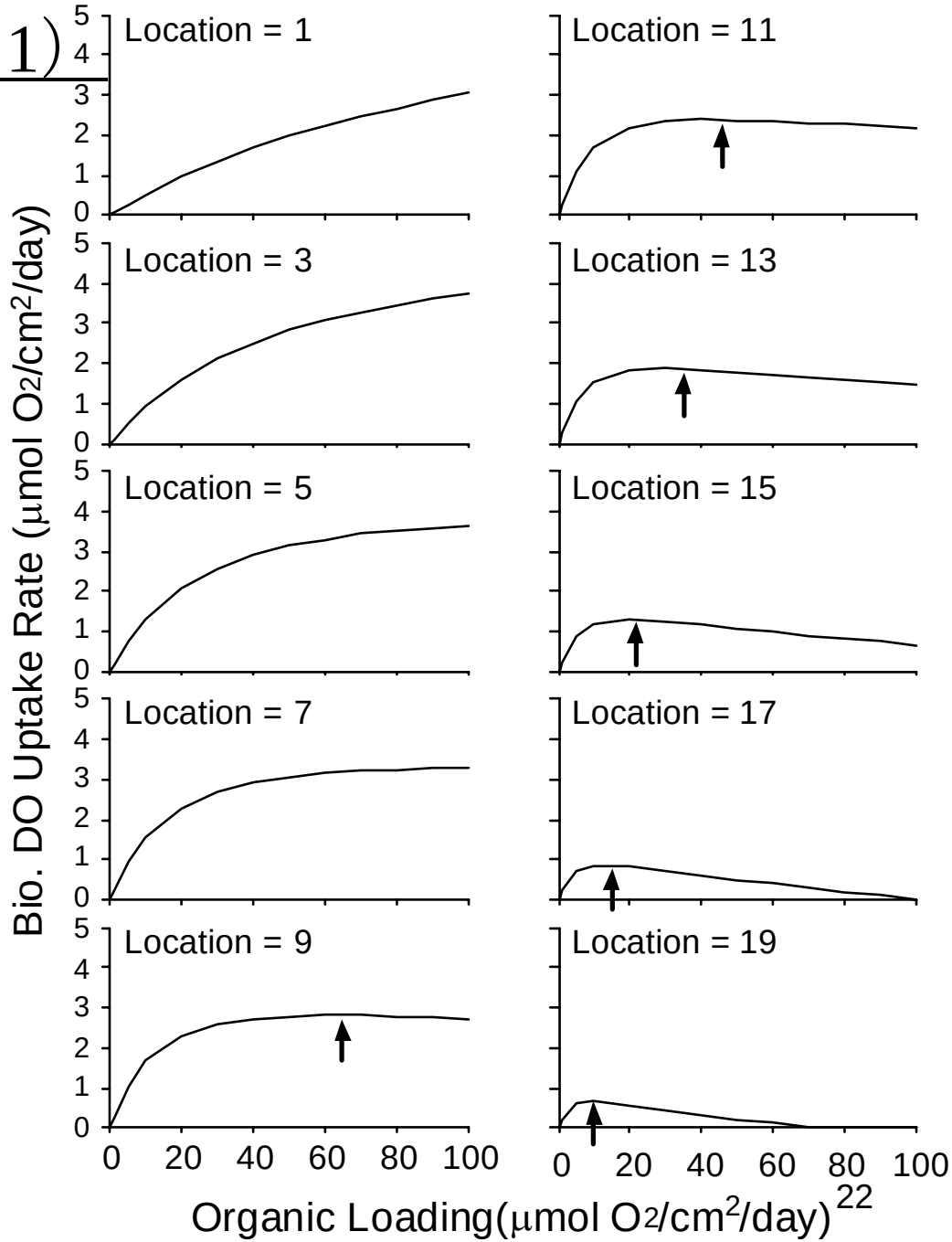


Reduced Substance Content in Sediment

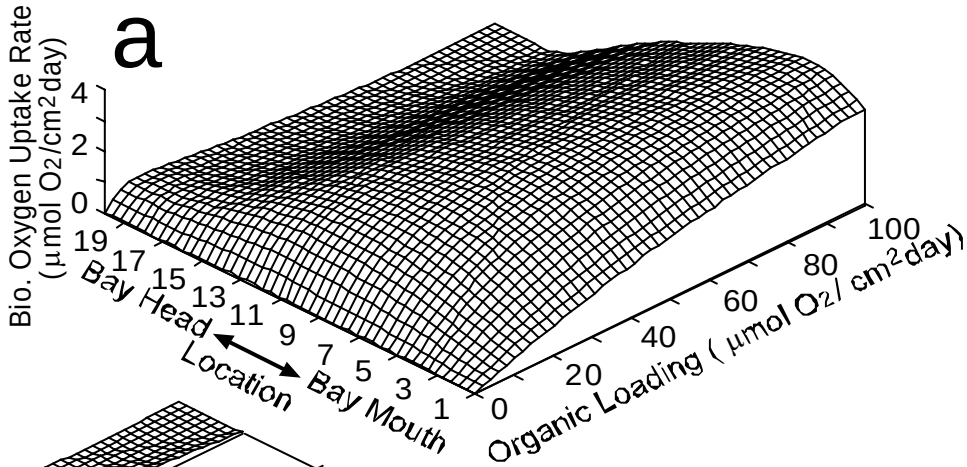
現場調査法の検証（Case 1）

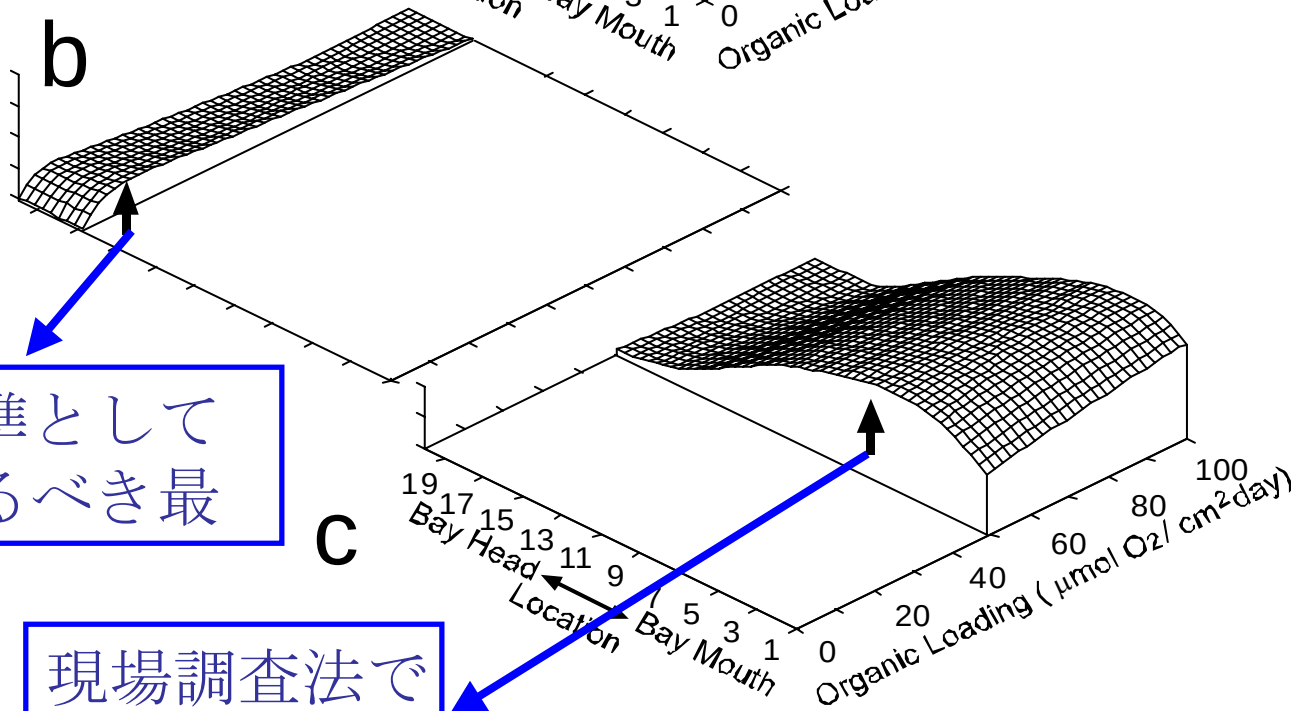


有機物負荷量を変えて計算を行い，各点での負荷許容量を求める



Results of the calculation by the three dimensional model





環境基準として
求めるべき最大値

現場調査法で
求まる最大値

Outline of "the Law to Ensure Sustainable Aquaculture Production"

Basic Guidelines

MAFF established "the Basic Guidelines".

Aquaculture Ground Improvement Program

Fisheries cooperative associations develop "the Aquaculture Ground Improvement Program". The governor approves the Program.

Recommendation

When a farm is in extreme deterioration, the governor recommends the cooperative to improve the farm environments.